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Alka Banker[1], Dolly Patel[2], Wasundhara Bhad[3], Sarala Manjappa Laxmikanth[4], Priyanka Kapoor[5], Aman Chowdhry[6], Jayasankar Purushothaman Pillai[7]

Establishing a Standard Transverse Maxillary Dimension on Study Casts Using the Intermolar-to-Intercanine Width Ratio: A Pan-India Study

Utvrđivanje standardne transverzalne maksilarne dimenzije na studijskim modelima korištenjem omjera intermolarne i interkanine širine: pan-indijska studija

[1] Bankers Hospital, Ahmedabad, India.
Bolnica Bankers, Ahmedabad, Indija
[2] Department of Orthodontics, AMC Dental College, Kokhra, Ahmedabad, India.
Zavod za ortodonciju Stomatološkog fakulteta AMC, Kokhra, Ahmedabad, Indija
[3] Government Dental College & Hospital Mumbai, St. George Hospital Premise, P.D. Melo Road Fort, Mumbai, India.
Državni stomatološki fakultet i bolnica Mumbai, prostor bolnice St. George, P. D. Melo Road Fort, Mumbai, Indija
[4] Department of Orthodontics, the Oxford Dental College, Bangalore, India.
Zavod za ortodonciju Stomatološkog fakulteta Oxford, Bangalore, Indija
[5] Orthodontics, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India.
Ortodoncija – Stomatološki fakultat, Jamia Millia Islamia, New Delhi, Indija
[6] Oral Pathology, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India.
Oralna patologija – Stomatološki fakultet, Jamia Millia Islamia, New Delhi, Indija
[7] Department of Oral and Maxillofacial Pathology, Government Dental College and Hospital, Ahmedabad, India
Zavod za oralnu i maksilofacijalnu patologiju Državnoga stomatološkog fakulteta i bolnice, Ahmedabad, Indija

Abstract

Background: Evaluation of maxillary width holds significant clinical importance in identifying developmental abnormalities, aiding in orthodontic diagnosis and treatment planning, providing ethnicity-specific data, and supporting forensic applications. Still, research on maxillary growth in transverse dimension is limited due to a lack of standardized diagnostic criteria and methods for defining normalcy. Addressing these gaps, this study aimed to establish a standard transverse maxillary dimension using the intermolar (IMW)-to-intercanine (ICW) width ratio determined on a large, homogeneous sample of dental Class I well-aligned arches with Little's irregularity index 1 or 2 across India. **Methods:** A pan-India, cross-sectional, model-based study of 1575 maxillary arch models with normal occlusion was conducted to define the transverse dimension of the maxillary arch. The IMW and the ICW linear dimensions and their ratio were measured and statistically analyzed. These parameters were also compared for sex-based differences. **Results:** The results revealed a mean IMW and ICW of 36.87mm and 35.44 mm, respectively. The mean ratio of IMW to ICW was 1.04. Sexual differentiation revealed a significantly higher mean values of IMW (37.54) and ICW (36.10) in males compared to females for IMW (35.84) and ICW (34.92), respectively, at p=0.000. **Conclusion:** In normal and well-aligned dentition, the ratio between IMW and ICW in the transverse dimension is 1.04:1. It provides a clinically easy visual evaluation chairside method to identify normal arches, even without radiographs. This norm can be further explored in diverse ethnic populations and explored for applications in orthodontic diagnosis and treatment planning, forensic odontology, and anthropological studies.

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Address for correspondence
Priyanka Kapoor, MD
Professor and Incharge, Orthodontics, Jamia Millia Islamia, Faculty of Dentistry
New Delhi, India.
Phone: +91-9891914997
pkapoor@jmi.ac.in

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Alka Banker - . ORCID: 0000-0001-8446-8011
Dolly Patel - . ORCID: 0000-0003-1490-656X
Wasundhara Bhad - ORCID: 0000-0001-7908-9199
Sarala Manjappa Laxmikanth - ORCID: 0009-0007-8290-8918
Priyanka Kapoor - ORCID: 0000-0002-7676-9743
Aman Chowdhry - ORCID: 0000-0001-6243-4152
Jayasankar Purushothaman Pillai - ORCID: 0000-0002-9101-7531

Background

The growth of the maxilla has been studied by various biological processes and methods including anthropological studies, paleontology, cephalometrics, comparative anatomy, and experimental biology (1). The transverse growth of maxilla is majorly influenced by mid-palatine sutural growth and remodeling. Regarding the timing of maxillary growth, it is estimated that sutural growth in combination with cartilaginous expansion ends at about seven years of age, following which the apposition at the surface plays a predominant role in growth (1). Since the growth of the maxilla shows growth cessation very early in life, it becomes extremely important to understand its norms and aberrations so that early intervention is possible for patients (2).

Interestingly, anthropology and evolutionary literature attempts to provide an insight pertaining to growth of facial structure in general, whereas orthodontic literature primarily focuses on the growth in three spatial planes and the effect of growth modulating appliances on jaw growth (1). Additionally, the influence of different facial types on the strength of masticatory muscles, presence of maxillary atresia, and the effect of orthodontic appliances in maxillary growth have been extensively studied in sagittal and vertical dimensions, but the growth studies in transverse dimension are still elusive (3 – 5). This can be due to multiple issues including trouble locating cephalometric landmarks, and their resulting reproducibility, standardizing the positioning of the head, magnification in the radiographs, and sample standardization.[6] However, in the past few years there have been some studies in which metallic implants were used for assessing the effect of certain functional appliances on the transverse growth of the maxilla (6, 7). A study by Monini et al used metallic implants in the maxilla and mandible and evaluated the changes in transverse maxillary dimension with growth and/or treatment with bionator appliance. They found statistically significant growth in all variables, excluding anterior maxillary implants distance.[6] Unfortunately, the effects on transverse growth shows paucity of literature and requires urgent attention due to its significant effects on facial structure and early identification of transverse discrepancies in growing patients to aid in early diagnosis and management.

Maxillary transverse growth deficiency holds high clinical relevance as it corresponds to conditions such as a high palate, crossbite, accentuated curve of Wilson, increased buccal corridors, missing teeth, and certain skeletal sagittal malocclusions (8 - 10). Interestingly, the maxillary width deficiency still lacks efficient analysis due to a lacuna in diagnostic criteria as well as diagnostic methods to define the normality in the transverse dimensions, as is available in other dimensions (11). The available literature presents evidence of certain criteria and formulas for diagnosing deficient arches but determining normal arch widths, still remains a challenge (4, 12 – 16).

Moreover, crossbites and maxillary constrictions frequently do not go hand in hand, which requires establishing the transverse norms for correctly diagnosing the latter, and planning the treatment to correct the occlusion, devel-

Uvod

Rast maksile proučavao se različitim biološkim procesima i metodama, uključujući antropološke studije, paleontologiju, kefalometriju, komparativnu anatomiju i eksperimentalnu biologiju (1). Na transverzalni rast gornje čeljusti uvelike utječu rast i remodeliranje sutura srednjeg nepca. Kad je riječ o rastu gornje čeljusti, procjenjuje se da suturalni rast u kombinaciji s hrskavičnim širenjem završava u dobi od oko sedam godina, nakon čega apozicija na površini ima dominantnu ulogu u rastu (1). Budući da rast gornje čeljusti prestaje vrlo rano, iznimno je važno razumjeti njezine norme i aberacije kako bi se pacijentima što prije moglo pomoći (2).

Zanimljivo je da autori antropoloških i evolucijskih knjiga pokušavaju dati uvid u rast struktura lica općenito, a ortodontska literatura uglavnom se fokusira na rast u trima prostornim ravninama i učinak aparata za modulaciju rasta na rast čeljusti (1). Dodatno, utjecaj različitih tipova lica na snagu žvačnih mišića, maksilarna atrezija i učinak ortodontskih naprava na rast maksile opsežno su proučavani u sagitalnoj i vertikalnoj dimenziji, ali studije o rastu u transverzalnoj dimenziji još su manjkave (3 – 5). To može biti posljedica višestrukih problema, uključujući poteškoće u lociranju kefalometrijskih orijentira i njihove ponovljivosti, standardiziranje pozicioniranja glave, povećanje na rendgenskim snimkama i standardizaciju uzoraka (6). No u posljednjih nekoliko godina bilo je studija u kojima su metalni implantati korišteni za procjenu učinka pojedinih funkcionalnih naprava na transverzalni rast maksile (6, 7). Monini i suradnici u svojem su se istraživanju koristili metalnim implantatima u gornjoj i donjoj čeljusti za procjenu promjene u transverzalnoj maksilarnoj dimenziji s rastom i/ili liječenjem bionatorom. Pronašli su statistički značajan rast u svim varijablama, osim kad je riječ o udaljenosti prednjih maksilarnih implantata (6). Nažalost, malo je literature o učincima na transverzalni rast što zahtijeva veću pozornost zbog značajnih učinaka na strukturu lica i ranu identifikaciju transverzalnih odstupanja kod pacijenata koji rastu kako bi se pomoglo u ranoj dijagnostici i liječenju.

Nedostatak transverzalnoga rasta maksile iznimno je klinički bitan zato što odgovara stanjima kao što su visoko nepce, križni zagriz, istaknuta Wilsonova krivulja, povećani bukalni koridori, nedostatak zuba i određene skeletalne sagitalne malokluzije (8 – 10). Zanimljivo je da o nedostatku maksilarne širine još uvijek nema učinkovite analize zato što nema dijagnostičkih kriterija i dijagnostičkih metoda za definiranje normalnosti u transverzalnim dimenzijama kao što je to dostupno za druge dimenzije (11). U dostupnoj literaturi ima dokaza o određenim kriterijima i formulama za dijagnosticiranje deficijentnih lukova, ali određivanje normalne širine luka još uvijek je izazov (4, 12 – 16).

Štoviše, križni zagrizi i suženja gornje čeljusti često ne idu ruku pod ruku, što zahtijeva utvrđivanje transverzalnih normi za njihovo ispravno dijagnosticiranje i planiranje terapije za korekciju okluzije, razvoja lica i bukalnih koridora, a time i estetike osmijeha. Sve veći broj dokaza povezuje nedostatne lukove s poremećajem disanja tijekom spavanja, što može snažno utjecati na tjelesno, mentalno i kognitivno zdravlje

opment of face, buccal corridors, and hence smile esthetics. A growing body of evidence links deficient arches to sleep-disordered breathing, which can profoundly affect physical, mental, and cognitive health (17). Additionally, arch width may have forensic significance in terms of establishing the ethnicity or sex determination of an individual. Studies have proven sexual dimorphism in arch widths based on differences in the intercanine width (ICW) and intermolar width (IMW) of males and females (18 – 20). Hence, the need for normative data in maxillary transverse measurements is evident, not only to assess growth disturbances, but also as an ethnic and sex determinant in establishing the arch width of a population (21).

A hypothesis of IMW-to-ICW ratio was proposed by Banker for defining normative and deficient arches, which found that 98.60% of normal arches had a ratio of 1:1 ± 0.05 (22, 23). This hypothesis may also help the anthropologists and forensic specialists in establishing further association with facial forms, stature and body types of individuals. Yet it requires further exploration.

Recognising the gap in the literature about the transverse maxillary data for normative values such as age, sex and ethnicity specific and its importance in the growth of craniofacial skeleton and the related disturbances, the authors in the current study intend to define the maxillary transverse norm.

The current study was planned with the aim to determine the average transverse inter-molar width (IMW) of permanent first molars and inter-canine width (ICW) of permanent canines and evaluate their ratio (ICW/IMW) in an ethnic Indian population in order to establish a transverse maxillary norm for an ideal normal arch.

Material and Methods

The study was planned as a retrospective multicentric pan India study on pre-treatment dental models collected from dental colleges across 6 zones namely – north, west, south, east, central and northeast (24). The zonal division was an attempt to gather a large sample and give equal representation to all the geographical areas, ethnic groups, as well as sex. Each geographical zone identified minimum one and maximum two dental colleges for sample collection.

Sample size calculation

A total of 1600 pairs of dental casts (267 from each zone) were selected as the subject samples, of which 1575 casts were used for evaluation. The sample size was derived based on the principal author's earlier study and using the sample size calculation formula:

N= Z^2*SD (1-SD)/ (CI), where Z= Confidence Level, SD= Standard Deviation CI= Confidence Interval (2, 23). With a Standard Deviation of 2.02 and Confidence Level of 95% (Z score= 1.96) and Confidence Interval of 0.05, the minimum sample size was estimated to be 1567. We enhanced the sample to 1600 to include the risk of loss or damage of few casts.

Casts of patients were selected on the basis of the following inclusion and exclusion criteria.

(17). Uz to, širina luka može imati forenzičko značenje kad je riječ i utvrđivanju etničke ili spolne pripadnosti pojedinca. Autori studija dokazali su spolni dimorfizam u širini luka na temelju razlika u interkaninoj širini (ICW) i intermolarnoj širini (IMW) muškaraca i žena (18 – 20). Zato je evidentna potreba za normativnim podatcima u maksilarnom transverzalnom mjerenju, ne samo za procjenu poremećaja u rastu, nego i kao etnička i spolna odrednica u određivanju širine luka u populaciji (21).

Banker je predložio hipotezu omjera IMW-a i ICW-a za definiranje normativnih i deficijentnih lukova koja je otkrila da 98,60 % normalnih lukova ima omjer 1 : 1 ± 0,05 (22, 23). Ta hipoteza također može pomoći antropolozima i forenzičarima u utvrđivanju daljnje povezanosti s oblicima lica, stasom i tipovima tijela pojedinaca. Ipak, potrebno je daljnje istraživanje.

Uzimajući u obzir nedostatnu literaturu o transverzalnim maksilarnim podatcima za normativne vrijednosti kao što su dob, spol i etnička pripadnost, te njihovu važnost u rastu kraniofacijalnoga kostura i s tim povezanim poremećajima, autori u ovoj studiji namjeravaju definirati maksilarnu transverzalnu normu.

Ova studija planirana je tako da se odredi prosječna transverzalna intermolarna širina (IMW) trajnih prvih kutnjaka i interkanina širina (ICW) trajnih očnjaka te procijeni njihov omjer (ICW/IMW) u etničkoj indijanskoj populaciji da bi se utvrdila transverzalna maksilarna norma za idealni normalni luk.

Materijali i metode

Istraživanje je planirano kao retrospektivna multicentrična panindijska studija na dentalnim modelima prije terapije prikupljenima na stomatološkim fakultetima u šest zona – sjever, zapad, jug, istok, srednji dio i sjeveroistok (24). Zonskom podjelom nastojalo se prikupiti veliki uzorak i dati jednaku zastupljenost svim geografskim područjima, etničkim skupinama te spolu. Svaka geografska zona imala je najmanje jedan i najviše dva stomatološka fakulteta za prikupljanje uzoraka.

Izračun veličine uzorka

Kao uzorak odabrano je ukupno 1600 pari dentalnih modela (267 iz svake zone) od kojih je 1575 odljeva korišteno za procjenu. Veličina uzorka određena je na temelju ranije studije glavnog autora i korištenjem formule za izračun veličine uzorka:

N= Z2*SD (1-SD)/ (CI), gdje je Z = razina pouzdanosti, SD = standardna devijacija CI = interval pouzdanosti (2, 23). Sa standardnom devijacijom od 2,02 i razinom pouzdanosti od 95 % (Z rezultat = 1,96) i intervalom pouzdanosti od 0,05, minimalna veličina uzorka procijenjena je na 1567. Uzorak smo povećali na 1600 kako bismo uključili rizik od gubitka ili oštećenja nekoliko modela.

Modeli pacijenata odabrani su na temelju kriterija za uključivanje i isključivanje.

Inclusion criteria

Subjects of Indian origin (three generations living in India); Age group 15-35 years; Presence of all teeth till first permanent molars in the maxillary arch; Class I dental occlusion with no or minimal crowding or spacing (Littles index 1 and 2), (25); Patients with average face with straight or convex profile and normal growth pattern; Normal overjet of 0-2mm (26).

Exclusion criteria

Early or late mixed dentition; Severe crowding or spacing in maxilla; Class III or Class II skeletal and dental malocclusion; Vertical or horizontal growth pattern.

Methodology

Protocols were defined for the inclusion as well as the measurement of casts before the start of the study. Training for evaluation of casts was conducted for all centers included in the study by the principal investigator through an online platform. Each zone deployed two trained orthodontists to independently perform the anatomical measurement of inter-molar (IMW) and inter-canine widths (ICW).

Measurement of ICW and IMW: Two trained orthodontists, using the digital Vernier caliper, accurate to 0.01 mm, measured the linear measurements, the ICW and the IMW in the maxillary dental models independently. The IMW was measured from left side of maxillary arch to the right side at the junction where the lingual groove of the maxillary first molar meets the palatal mucosa, as taken in Mc Namara (2003), (27). The ICW was measured from the canine tip of left to right side of the maxillary arch (Figure 1), (23).

Kriteriji za uključivanje

1. subjekti indijskog podrijetla (tri naraštaja žive u Indiji); 2. dobna skupina od 15 do 35 godina; 3. prisutnost svih zuba do prvih trajnih kutnjaka u čeljusnom luku; 4. dentalna okluzija klase I bez minimalne kompresije ili razmaka ili s minimalnom kompresijom ili razmacima (Littlesov indeks 1 i 2) (25); 5. pacijenti s prosječnim licem s ravnim ili konveksnim profilom i normalnim uzorkom rasta; 6. normalan horizontalni preklop (overjet) od 0 do 2 mm (26).

Kriteriji za isključivanje

1. rana ili kasna mješovita denticija; 2. ozbiljna kompresija ili razmaci u maksili; 3. klasa III ili klasa II skeletalne i dentalne malokluzije; 4. vertikalni ili horizontalni obrazac rasta.

Metodologija

Definirani su protokoli za uključivanje i mjerenje modela prije početka studije. Glavni istraživač educirao je suradnike za procjenu modela za sve centre uključene u studiju putem online platforme. Svaka zona zadužila je dva educirana ortodonta da neovisno obavljaju anatomsko mjerenje intermolarne (IMW) i interkanine širine (ICW).

Mjerenje ICW-a i IMW-a: dva educirana ortodonta neovisno su mjerila linearne mjere ICW-a i IMW-a na maksilarnim dentalnim modelima koristeći se digitalnim Vernierovim kaliperom točnosti do 0,01 mm. IMW je izmjeren od lijeve strane maksilarnoga luka prema desnoj na spoju gdje se lingvalni žlijeb prvoga maksilarnoga molara susreće sa sluznicom nepca, prema Mc Namari (2003) (27). ICW je izmjeren od vrha očnjaka s lijeve na desnu stranu maksilarnoga luka (slika 1.) (23).

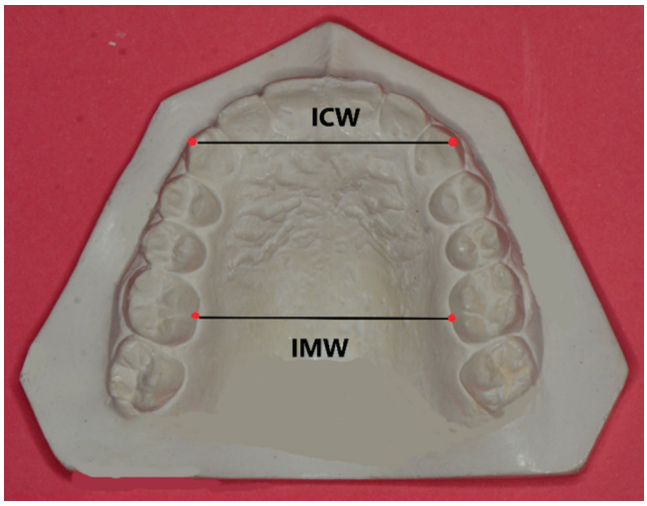

Figure 1 Landmarks of measurement of inter-canine and inter-molar widths
ICW: Intercanine width, IMW: Intermolar width
The intermolar width was measured from left side of maxillary arch to the right side at the junction where the lingual groove of the maxillary first molar meets the palatal mucosa. The ICW was measured from the canine tip of left to right side of the maxillary arch.
Slika 1. Orijentiri mjerenja interkanine i intermolarne širine
ICW: Interkanina širina, IMW: Intermolarna širina
Intermolarna širina mjerena je od lijeve strane gornje čeljusti do desne strane na spoju gdje se lingvalni žlijeb gornjega prvog kutnjaka susreće sa sluznicom nepca. ICW je mjeren od vrha očnjaka s lijeve na desnu stranu maksilarnog luka.

Data entry

The measured data were entered in Microsoft Office Excel® 2007 (Microsoft®, Redmond, Washington, USA) formulated and shared by the principal investigator with all the centers and then used for further statistical analysis. Before entering the values for ICW and IMW, the patient identity was blinded by giving them a unique ID as per the name of each centre. The entries were designated separately for males and females. The ratio was automatically calculated for IMW: ICW width in the Excel sheet.

Statistical Analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS) software (SPSS for Windows, V.16.0. SPSS Inc., Chicago, IL, USA; now IBM Corp., Armonk, USA). A *p*-value of <0.05 was set as statistically significant. The normality of the data distribution was checked using the Shapiro-Wilks test and by the visual analysis of the normal Q–Q plots for the measured variables, the ICW and the IMW values. The measurement error and the inter-observer reliability of the measurements were tested using Dahlberg's formula and intraclass correlation coefficient (ICC), respectively (28). To apply Dahlberg's formula and the ICC, the measurements of ICW and IMW were recorded individually by two trained orthodontists using the same set of 30 models and the same Vernier caliper, at a gap of one month prior to the start of the main study. The Wilcoxon signed ranks test was used to compare the mean values of IMW and ICW.

Results

Out of the total number of 1600 casts collected from all centers, 1575 (98.4%) casts were analyzed as they completely fit the inclusion and exclusion criteria. Out of the total number of 1575 casts analyzed, the data for males and females were unclear in some entries due to retrospective records. Hence, for sex differences, a total of 1025 (65.8%) casts were analyzed. Of these, 435 were males (42.4%) and 590 were females (57.6%).

Sample Characteristics

The Shapiro-Wilks test (p>0.05) and a visual inspection of their histograms and the normal Q-Q plots showed that the values of both ICW and IMW were not normally distributed, with skewness of 0.0.063 (SE=0.062) and kurtosis of 0.593 (SE= 0.0.123) for the IMW and skewness of 0.273 (SE=0.0.062) and kurtosis of 1.287 (SE= 0.123) for the ICW.

IMW and ICW measurements

The results of the Dahlberg formula and ICC revealed an excellent reliability of the measured data. (Table 1) The mean values of the measured variables are shown in Table 2. The Wilcoxon signed rank test revealed a significant difference in the mean values of ICW and IMW. The study revealed a mean ratio of 1.04:1 between IMW and ICW. It was observed that 33.1% of the dental models revealed a ratio of ≤1.00 and the remaining had a ratio of >1.00 (Table 3).

Unošenje podataka

Izmjereni podatci uneseni su u Microsoft Office Excel® 2007 (Microsoft®, Redmond, Washington, SAD), glavni istraživač ih je formulirao i poslao svim centrima, a zatim su korišteni za daljnju statističku analizu. Prije unosa vrijednosti ICW-a i IMW-a, identitet pacijenta je zaslijepljen davanjem jedinstvenoga ID-a prema nazivu svakoga centra. Prijave su bile označene odvojeno za muškarce i žene. Omjer je automatski izračunat za IMW: ICW u tablici Excela.

Statistička analiza

Podatci su analizirani s pomoću softvera Statistical Package for Social Sciences (SPSS) (SPSS za Windows, V.16.0. SPSS Inc., Chicago, IL, SAD; sada IBM Corp., Armonk, SAD). P-vrijednost < 0,05 postavljena je kao statistički značajna. Normalnost distribucije podataka provjerena je Shapiro-Wilksovim testom i vizualnom analizom normalnih Q – Q dijagrama za izmjerene varijable, ICW i IMW vrijednosti. Pogreška u mjerenju i međupromatračka pouzdanost mjerenja testirani su korištenjem Dahlbergove formule i unutarrazrednoga koeficijenta korelacije (ICC) (28). Da bi se primijenila Dahlbergova formula i ICC, mjerenja ICW-a i IMW-a pojedinačno su zabilježila dva educirana ortodonta koristeći se istim setom od 30 modela i jednakim Vernierovim kaliperom, u razmaku od mjesec dana prije početka glavne studije. Wilcoxonov test rangiranja s predznakom korišten je za usporedbu srednjih vrijednosti IMW-a i ICW-a.

Rezultati

Od ukupnog broja od 1600 modela prikupljenih iz svih centara, 1575 (98,4 %) analizirano je jer su potpuno zadovoljavali kriterije za uključivanje i isključivanje. Od ukupno 1575 analiziranih modela, podatci za muškarce i žene u nekim su zapisima bili nejasni zbog retrospektivnog unošenja. Dakle, za spolne razlike analizirano je ukupno 1025 (65,8 %) modela. Od toga je bilo 435 muškaraca (42,4 %) i 590 žena (57,6 %).

Obilježja uzoraka

Shapiro-Wilksov test (p > 0,05) i vizualni pregled njihovih histograma i normalnih Q – Q dijagrama pokazali su da vrijednosti te ICW i IMW nisu normalno raspoređeni, s asimetrijom od 0,0,063 (SE = 0,062) i kurtozom od 0,593 (SE = 0,0,123) za IMW te asimetrijom od 0,273 (SE = 0,0,062) i kurtozom od 1,287 (SE = 0,123) za ICW.

Mjerenja IMW-a i ICW-a

Rezultati Dahlbergove formule i ICC-a otkrili su izvrsnu pouzdanost izmjerenih podataka. (tablica 1.). Srednje vrijednosti izmjerenih varijabli prikazane su u tablici 2. Wilcoxonov test ranga s predznakom otkrio je značajnu razliku u srednjim vrijednostima ICW-a i IMW-a. Studija je otkrila srednji omjer od 1,04 : 1 između IMW-a i ICW-a. Uočeno je da je 33,1 % dentalnih modela pokazalo omjer ≤ 1,00, a preostali su imali omjer > 1,00 (tablica 3.).

Table 1 Table showing the measurement error and inter-observer reliability of the measured data
Tablica 1. Tablica koja prikazuje pogrešku u mjerenju i pouzdanost izmjerenih podataka među promatračima

Variable • Variajbla	Observer • Promatrač	n	Mean • Srednja vrijednost (mm.)	SD	Dahlberg's value • Dahlbergova vrijednost	ICC Cronbach's Alpha
IMW	I	30	37.46	2.54	0.45	0.987
	II	30	37.08	2.51		
ICW	I	30	35.05	2.33	0.32	0.985
	II	30-	34.90	2.19		

ICC: intraclass correlation coefficient (ICC) • koeficijent međurazredne korelacije (ICC), ICW: Intercanine width • interkanina širina, IMW: Intermolar width • intermolarna širina

Table 2 Table showing the results of the descriptive statistics of the measured variables
Tablica 2. Tablica s rezultatima deskriptivne statistike mjerenih varijabli

Variable • Varijabla	N	Mean • Srednja vrijednost mm	Std. Deviation • Std. devijacija	Z	Sig* • P*
IMW	1575	36.87	3.07	-17.41	0.000
ICW		35.44	3.09		
Ratio • Omjer		1.04	0.08		

Table 3 Table showing the frequency distribution of the models according to the ratio between IMW and ICW values
Tablica 3. Tablica koja prikazuje distribuciju učestalosti modela prema omjeru između IMW i ICW vrijednosti

IMW/ICW Ratio	n	%
0.76-0.99	426	27%
1.00	96	6.1%
>1.00	1053	66.9%

*Significant at P<0.05 • Razina značajnosti P < 0,05

Sex differentiation

The comparison of the means between male and female subjects revealed a highly significant difference in the measured parameters and a significant difference for the ratio. The males had a significantly higher mean values of IMW (37.54) and ICW (36.10) compared to females for IMW (35.84) and ICW (34.92) respectively at p=0.000, (Table 4).

Diferencijacija prema spolu

Usporedba srednjih vrijednosti muških i ženskih ispitanika pokazala je iznimno veliku razliku u mjerenim parametrima i značajnu razliku u omjeru. Muškarci su imali značajno više srednje vrijednosti IMW-a (37,54) i ICW-a (36,10) u usporedbi sa ženama za IMW (35,84), odnosno ICW (34,92) pri p = 0,000 (tablica 4.).

Table 4 Sex differences in the measured parameters and their ratio
Tablica 4. Spolne razlike u mjerenim parametrima i njihov omjer

Sex • Spol	N	IMW		ICW		Ratio	
		Mean • Srednja vrijednost	SD	Mean • Srednja vrijednost	SD	Mean • Srednja vrijednost	SD
Male • Muški	435	37.54	3.09	36.10	3.33	1.04	0.09
Female • Ženski	590	35.84	2.78	34.92	3.07	1.03	0.09
Overall • Ukupno	1025	36.56	3.04	35.42	3.23	1.04	0.09
Sig*.		0.000		0.000		0.015	

*Significant at P<0.05 • Razina značajnosti P < 0,05

Discussion

The results of our study revealed a mean ratio of 1.04 between IMW and ICW, which is proposed as standard maxillary transverse width norm for a Class I normal occlusion arch forms. The strengths of our study and proposition lie in the fact that our data are collected from a huge sample of 1575 from all six different geographical zones with no bias of ethnicity or geographical boundaries with India. This establishes a transverse maxillary width norm which is currently documented from the data of ethnic populations in

Rasprava

Rezultati naše studije otkrili su srednji omjer od 1,04 između IMW-a i ICW-a, što je predloženo kao standardna norma maksilarne transverzalne širine za normalne oblike okluzijskoga luka klase I. Snaga naše studije i prijedloga jest u činjenici da su naši podatci prikupljeni iz golemoga uzorka od 1575 iz svih šest različitih zemljopisnih zona bez pristranosti prema etničkoj pripadnosti ili zemljopisnim granicama s Indijom. To uspostavlja normu transverzalne maksilarne širine koja je trenutačno dokumentirana iz podataka o

India, but we propose it to be tested across the geographical boundaries of the world. This study has explored the normal width in the anterior as well as the posterior region of the maxillary arch to explore the complex interplay of age, sex, and ethnicity in transverse dimensions, which remain inadequately explored. We comply by the criterion of a "norm" encompassing not a solitary numerical value but rather an encompassing spectrum of values, which aptly represent the substantial diversity found among individuals, defying encapsulation within a solitary figure. Even anthropological research on skeletal remains has shown the narrowing of jaws in the post-industrial, modern world, thus highlighting the requirement of re-evaluation of the "norms" (20).

The transverse norms till date are primarily dependent on a single metric, e.g. IMW and ICW individually. Researchers have noted variations in these dimensions, hence using a ratio formed from two measurements, such as the IMW/ICW ratio used in the current study, reduces the dependence on a single metric and limits the discrepancies (21 – 23). This may have a direct implication on the treatment planning for the patients. McNamara observed that a maxillary arch with a transpalatal width of 36 to 39 mm could accommodate a dentition of average size without crowding or spacing, while a width of less than 31 mm may result in crowded arches and may need surgical or orthopedic expansion (8). Singularly using the transpalatal width values may be sometimes misleading. Further, to comprehend the growth of craniofacial complex that has a direct bearing on the three spatial dimensions of maxilla and identify its variations in the form of syndromes, establishing these norms become extremely important (29).

Our study documented a mean IMW of 36.87 mm ± 3.07, mean ICW of 35.44 mm±3.09, and the mean ratio of IMW to ICW at 1.04:1 (SD 0.08). A previous pilot study by the authors has established that well-formed arches exhibit an IMW: ICW ratio of 1:1 ±0.5, and if the ratio between IMW: ICW is less than 1.15; the subject can be identified as having narrow arches (23). Additionally, the study identified the arches as broad with an IMW of greater than 37.45mm, and narrow if less than 34.92mm. But the study sample was small comprising of 151 maxillary casts, and not including diverse population data, hence it could not be put forward as a norm. Thus, the authors extended the study to a pan-India sample with normal occlusion casts to remove the bias present in the previous study.

Numerous studies have also noted sex differences, particularly larger maxillary arch widths in males (16, 18, 19). This was consistent with the results of our study which showed a statistically significant difference in the average ratio of IMW to ICW in males and females at 1.04 and 1.03, respectively (p=0.015). Another longitudinal study on posteroanterior cephalograms of 25 males and 25 females which investigated the

changes in maxillary width showed an average difference of 2mm from 2-6 years, and 6.2 mm at 18 years between males and females, achieving the final width at 15 and 16 years in males and females, respectively.(20) A study evaluating the palate of adults and children in 300 casts also

etničkim populacijama u Indiji, ali predlažemo da se testira u sklopu geografskih granica svijeta. U ovoj je studiji istražena normalna širina u prednjoj i stražnjoj regiji maksilarnoga luka kako bi se analizirala složena interakcija dobi, spola i etničke pripadnosti u transverzalnim dimenzijama koje su i dalje nedovoljno istražene. Držimo se kriterija norme koja ne obuhvaća samo numeričku vrijednost, nego sveobuhvatni spektar vrijednosti koje prikladno čine značajnu raznolikost koja se nalazi među pojedincima, prkoseći inkapsulaciji unutar usamljene figure.

Čak su i antropološka istraživanja skeletnih ostataka pokazala sužavanje čeljusti u poslijeindustrijskome, modernome svijetu, ističući tako potrebu reevaluacije *normi* (20).

Transverzalne norme do danas uglavnom ovise o jednoj metrici, npr. IMW-u i ICW-u pojedinačno. Istraživači su uočili varijacije u tim dimenzijama, zato korištenje omjera formiranoga od dvaju mjerenja, kao što je omjer IMW/ICW koji se koristi u ovoj studiji, smanjuje ovisnost o jednoj metrici i ograničava odstupanja (21 – 23). To može izravno utjecati na planiranje terapije pacijenata. McNamara je uočio da maksilarni luk transpalatinalne širine od 36 do 39 mm može prihvatiti denticiju prosječne veličine bez kompresije ili razmaka, a širina manja od 31 mm može rezultirati zbijenim lukovima i možda će trebati kirurško ili ortopedsko proširenje (8). Pojedinačno korištenje vrijednosti transpalatinalne širine katkad može dovesti u zabludu. Nadalje, za razumijevanje rasta kraniofacijalnog kompleksa koji izravno utječe na tri prostorne dimenzije maksile i identificiranje njegovih varijacija u obliku sindroma, utvrđivanje tih normi postaje iznimno važno (29).

U našoj je studiji dokumentirana srednja vrijednost IMW-a od 36,87 mm + 3,07, srednja vrijednost ICW-a od 35,44 mm + 3,09 i srednji omjer IMW-a prema ICW-u od 1,04 : 1 (SD 0,08). Prethodna pilot-studija autora utvrdila je da dobro oblikovani lukovi pokazuju omjer IMW: ICW od 1 : 1 ±0,5, a ako je omjer između IMWa : ICW-a manji od 1,15 može se reći da subjekt ima uske lukove (23). Dodatno, istraživanje identificiralo je lukove kao široke s IMW-om većim od 37,45 mm i kao uske ako su manji od 34,92 mm. Ali uzorak u studiji bio je malen i sastojao se od 151 modela gornje čeljusti, a nije uključivao različite podatke o populaciji i zato se nije mogao istaknuti kao norma. Zato su autori proširili studiju na panindijski uzorak s normalnim modelima kako bi uklonili pristranost u prijašnjoj studiji.

U mnogobrojnim studijama također su ustanovljene spolne razlike, posebice veća širina maksilarnoga luka u muškaraca (16, 18, 19). To je bilo u skladu s rezultatima naše studije koja je pokazala statistički značajnu razliku u prosječnom omjeru IMW-a prema ICW-u kod muškaraca i žena od 1,04, odnosno 1,03 (p = 0,015). U drugoj longitudinalnoj studiji na posteroanteriornim cefalogramima 25 muškaraca i 25 žena kojom su se istraživale promjene u maksilarnoj širini istaknuta je prosječna razlika od 2 mm u dobi od 2 do 6 godina i 6,2 mm u dobi od 18 godina između muškaraca i žena te je postignuta konačna širina u dobi od 15, odnosno 16 godina kod muškaraca i žena (20). Autori studije u kojoj se procjenjuje nepce odraslih i djece na 300 modela također su dokumentirali veće palatinalne duljine, širine, dubine i veličine

documented higher measurements of palatal length, width, depth, and size of the dental papilla in males of both the groups. Further, their comprehensive logistic regression model incorporating all three predictors (length, width, and depth) demonstrated significant correlations with sex within the adult group (30).

Across different populations worldwide, distinct anthropometric criteria are needed to determine the sex of unidentified skeletal remains from those populations. Forensic specialists, anthropologists, and archaeologists encounter difficulties in estimating the sex of fragmented, buried, or burned remains due to the often-limited availability of morphological indicators of differences. Jaw bones, such as the mandible and maxilla, which are commonly found with other skeletal elements, exhibit considerable sexual dimorphism. Hence, establishing parameters in maxillary width for sexual dimorphism as well as associated *rugae* pattern can aid in reconstructive identification of an individual (31 – 34).Besides studies have also documented maxillary arch width differences in relation to various skeletal classifications of malocclusion which determine the facial shape and profile. (35)

This study has thus explored the concept of maxillary width from the a linear IMW, ICW approach as well as a width ratio (IMW/ICW), which holds a significant advantage compared to linear approach. It can thus be proposed as a norm that can be explored in diverse ethnic populations using a robust standard methodology. The advantages of the current study involve the application of these parameters on a large ethnically homogeneous pool of subjects. The ratio-based approach, irrespective of age or sex, presents a straightforward and visually clear methodology, rendering it clinically feasible even in the absence of radiographic assistance. Nevertheless, it also puts forth a limitation of using a manual approach of measurement which can be prone to some bias.

Future scope

It can be further modified to a standard life size photographic technique for procuring the 3-D casts, identifying the landmarks and performing digitized measurements through software which can mitigate the bias. This can also enable an artificial intelligence-based machine learning algorithm to further differentiate between normal and narrow arches (36). It can have multiple applications in orthodontic diagnosis, treatment planning, study of development disturbances, anthropological studies in diverse ethnic populations, forensic data generation, and many more.

Conclusion

The average IMW to ICW ratio among individuals with normal and well-aligned dentition was documented as 1.04 from the data of ethnic populations across India. Sexual differentiation revealed a significantly higher mean values of IMW (37.54mm) and ICW (36.10mm) compared to females for IMW (35.84mm) and ICW (34.92mm), respectively, at p=0.000. The study presents a general maxillary width norm of approximately 1:1 ratio as a simple, easy, chairside aid to the clinician to identify normal or narrow arches. This study will aid the clinicians in diagnosis and treatment planning

zubne papile kod muškaraca u objema skupinama. Nadalje, njihov sveobuhvatni logistički regresijski model koji uključuje sva tri prediktora (dužinu, širinu i dubinu) pokazao je značajne korelacije sa spolom unutar skupine odraslih (30).

U različitim populacijama diljem svijeta potrebni su različiti antropometrijski kriteriji za određivanje spola neidentificiranih skeletnih ostataka tih populacija. Forenzičari, antropolozi i arheolozi nailaze na poteškoće u procjeni spola fragmentiranih, zakopanih ili spaljenih ostataka zbog često ograničene dostupnosti morfoloških pokazatelja razlika. Čeljusne kosti, kao što su mandibula i maksila, koje se obično nalaze s drugim elementima kostura, pokazuju značajan spolni dimorfizam. Zato utvrđivanje parametara u širini maksilarnoga luka za spolni dimorfizam te povezanog uzorka nabora može pomoći u rekonstruktivnoj identifikaciji pojedinca (31 – 34). Osim toga, u studijama su također dokumentirane razlike u širini maksilarnoga luka u odnosu na različite skeletne klasifikacije malokluzije koje određuju oblik i profil lica (35).

U ovoj studij zato je istražen koncept maksilarne širine iz linearnoga IMW-a i ICW-a te omjer širine (IMW/ICW) koji ima značajnu prednost u usporedbi s linearnim pristupom. Zato se može predložiti kao norma za istraživanje u različitim etničkim populacijama korištenjem robusne standardne metodologije. Prednosti ovog istraživanja uključuju primjenu tih parametara na veliki etnički homogeni skup ispitanika. Pristup koji se temelji na omjeru, bez obzira na dob ili spol, jednostavna je i vizualno jasna metodologija, što ga čini klinički izvedivim čak i bez radiografske pomoći. Unatoč tomu, također ograničava manualni pristup mjerenju koji može biti podložan određenoj pristranosti.

Buduća primjena

Može se dalje modificirati u standardnu fotografsku tehniku u prirodnoj veličini za dobivanje 3D modela, identificiranje orijentira i obavljanje digitaliziranih mjerenja softverom što može ublažiti pristranost. To također može omogućiti algoritmu strojnog učenja temeljenom na umjetnoj inteligenciji da dodatno razlikuje normalne i uske lukove (36). Može imati višestruku primjenu u ortodontskoj dijagnostici, planiranju liječenja, proučavanju razvojnih poremećaja, antropološkim studijama u različitim etničkim populacijama, stvaranju forenzičkih podataka i još mnogo toga.

Zaključak

Prosječni omjer IMW-a prema ICW-u među pojedincima s normalnom i dobro poravnatom denticijom dokumentiran je kao 1,04 iz podataka o etničkim populacijama diljem Indije. Diferencijacija prema spolu pokazala je značajno više srednje vrijednosti IMW-a (37,54 mm) i ICW-a (36,10 mm) u usporedbi sa ženama za IMW (35,84 mm), odnosno ICW (34,92 mm), pri p = 0,000. Studija daje opću normu širine gornje čeljusti od približno 1 : 1 omjera kao jednostavnu pomoć kliničaru za prepoznavanje normalnih ili uskih lukova. Ova će studija pomoći kliničarima u dijagnozi i planira-

and its potential applications extend to all branches of dentistry including orthodontics, forensic odontology, and anthropological studies.

Conflict of Interest: There is no conflict of interest

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nju terapije, a njezine se potencijalne primjene proširuju na sve grane stomatologije, uključujući ortodonciju, forenzičku odontologiju i antropološke studije.

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Doprinos autora: **A. B.** – osmišljavanje projekta, glavne ideje, nacrt i pisanje teksta; **D. P.** – osmišljavanje projekta, glavne ideje, nacrt; **W. B. i S. M. L.** – razrađivanje tehničkih detalja, doprinos realizaciji projekta; **P. K.** – osmišljavanje i provedba istraživanja, analiziranje rezultata te pisanje teksta i korespondencija; **A. C. i J. P. P.** – osmišljavanje i provedba istraživanja, analiziranje rezultata i pisanje teksta.

Sažetak

Svrha rada: Procjena maksilarne širine klinički je veoma važna u prepoznavanju razvojnih anomalija, ortodontskoj dijagnostici i planiranju terapije, pružanju podataka specifičnih za etničku pripadnost i u forenzici. Ipak, istraživanja maksilarnoga rasta u transverzalnoj dimenziji ograničena su zbog nedostatka standardiziranih dijagnostičkih kriterija i metoda za definiranje normalnosti. Rješavajući te nedostatke, cilj ovog istraživanja bio je uspostaviti standardnu transverzalnu maksilarnu dimenziju korištenjem omjera intermolarne (IMW) i interkanine širine (ICW) određenog na velikome homogenom uzorku dobro poravnatih zubnih lukova klase I Littleovim indeksom nepravilnosti 1 ili 2 diljem Indije. **Metode:** Provedena je panindijska presječna studija na temelju 1575 modela maksilarnoga luka s normalnom okluzijom da bi se definirala transverzalna dimenzija gornjega luka. Izmjerene su i statistički analizirane linearne dimenzije IMW-a i ICW-a te njihov omjer. Ti su parametri također uspoređeni s obzirom na razlike prema spolu. **Rezultati:** Rezultati su otkrili prosječan IMW i ICW od 36,87 mm, odnosno 35,44 mm. Srednji omjer IMW-a prema ICW-u bio je 1,04. Diferencijacija prema spolu pokazala je značajno više srednje vrijednosti IMW-a (37,54) i ICW-a (36,10) kod muškaraca u usporedbi s ženama za IMW (35,84) i ICW (34,92)(p = 0,000). **Zaključak:** U normalnoj i dobro poravnatoj denticiji omjer između IMW-a i ICW-a u transverzalnoj dimenziji iznosi 1,04 : 1. Omogućuje klinički jednostavnu metodu vizualnog prepoznavanja normalnih lukova čak i bez radiografije. Ta se norma može dalje istraživati u različitim etničkim populacijama i analizirati za primjenu u ortodontskoj dijagnostici i planiranju terapije, forenzičkoj odontologiji i antropološkim studijama.

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Adresa za dopisivanje
Priyanka Kapoor, MD
Professor and Incharge, Orthodontics, Jamia Millia Islamia, Faculty of Dentistry
New Delhi, India
tel: +91-9891914997
pkapoor@jmi.ac.in

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